Final Report

Project acronym: *HEI-Coat*

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M-ERA.NET Call 2016

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Publishable project summary

The HEI-Coat project aimed to develop CerMet innovative coatings for the replacement of Hard Chrome with environmentally friendly solutions, more sustainable with respect of HC. Coated hydraulic cylinders demonstrators were validated for 70000 cycles sliding in dry conditions trials vs reference HC coated shafts.
Environmental concerns associated with disposal of the plating Cr (VI) deposition bath, harmful for humans as well, has stimulated the worldwide research for alternative to Hard Chrome with the aim of its replacement.
When application is extreme and ambient harsh, hard carbides based CerMets are a viable alternative to HC.
Indeed, the need of compliance with the REACH regulation and for the criticalities due to raw materials shortage is a concern for CerMets as well: WC-Co is in the blacklist of Critical Raw Materials (CRMs), i.e. strategic materials for the European Economy.
Nevertheless, CerMet still appear as a perfect 'composite' material.
In HEI-Coat Project coatings from formulations with a low content/free of CRMs have been investigated.The High Pressure Cold Gas Spray, a relatively recent techniques, and the traditional Electroplating were the main methods for coatings deposition, and as additional reference techniques Low Pressure CGS and HVOF.
The 'cold' GS technique offers the valuable advantages of allowing hard coatings deposition with the control of decarburization phenomena, that means no phase changes. In HEI-Coat, dense coatings have been deposited from powders blends of AISI 304, Ti and Co as matrices and different percentages of ceramic particles. Customized powders were prepared by High Energy Mechanical Alloying were TiC 60%-AISI 304 40 % and TiC 75%-AISI 304 25%, (% volumetric fraction); another matrix/reinforcement mix was WC 50% Ti 50% (vol) while WC 83%–Co 17% (%wt) was a commercial blend.
DOE method was adopted for CerMets coatings deposition optimization.
For the Ectroplating, having advantages of aqueous baths, a low-cost electrolysis cell, an ideal combination of pressure, temperature and flexibility for the industrial scaling up, CerMets coatings meeting the specifications for hydraulic applications **(**Ra<0,25µm**)** were developed. Development of methodologies for codepositing particles and matrix, and for the modification of the composition electroplating bath allowed to achieve fast growth rate reaching 3 µm/min. One of the tested matrix, Ni-P was modified by SiC, graphite and PTFE. Matrix Fe-Cr and Cr (III)/SiC alternatives have been investigated as well.
In addition to HC, optimized HVOF WCCoCr modified with graphite layer for friction minimization was the further reference system. Although presenting sufficient tribological and corrosion resistance performances, coatings produced by LPCGS cannot meet the specifications due to a lack of hardness.
Extensive functional characterisation for mechanical, tribological and corrosion properties evidenced the best candidates for the final trials within homogenous groups of coatings. Electroplated Ni-P was the selected coating having corrosion that exceeded the specifications, hardness (900–1000 HV) superior to that of HC, wear rate and coefficient of friction in accordance with the specifications. In addition, the modified Ni-P-PTFE with porous morphology was selected for its originality, innovative aspects and low friction coefficient. A tailored solution was a bilayer design Ni-P/Ni-P-PTFE with optimized adhesion and with the sublayer providing hardness and corrosion resistance to the overall piece. For HPCGS the selected coating was the innovative TiC 60% - AISI 304 40% with an average friction coefficient slightly higher than HC, but with wear rate one magnitude lower (4.40·10-6 mm3/Nm). The hardness of TiC-AISI 304 reached almost 1100 $HV_{0.1}$, that could be indicative of a good resistance to abrasive wear. Four groups of rods manufactured of 20MnV6 steel were coated for final trials in a bench. The TiC - AISI 304 (115 µm), Ni-P (100 µm) and WCCoCr - graphite (660 µm) coated rods were characterized as elaborated and after ±70000 cycles sliding in dry conditions vs HC (25 µm). All the coatings passed the test with no, or small, significant oil leakage during trials resembling the HC behaviour and some damage for WC based coating that abraded the high speed type seals and maybe should be slightly improved, being interesting and performant. Cost analysis evidenced that new solutions are comparative to HC. In conclusion, coatings successfully developed in HEI-Coat Project and tested in the adopted dry conditions by the test-rig are suitable for HC substitution; furthermore HPCGS TiC-AISI 304 Fe based coatings are more eco-friendly than HC and free of dangerous elements like Co and W.